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TAWS Ensembles for Use in IWEDA

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ABSTRACT

Providing tactical commanders/users with quantitative detection range information for specific target/sensor pairings and environmental conditions is a desirable capability. However, providing this information for all scenarios (i.e., targets, sensors, locations, etc) in near real time is not realistic given the current processing power of tactical computers and the availability of high resolution environmental data (in both space and time). As a result, for planning purposes and initial screening of potential target acquisition devices (e.g.. IR devices vs. image intensifiers) a simple rule based application can provide valuable guidance. Such an application exists and is fielded via the Army Battle Command System (ABCS) – the Integrated Weather Effects Decision Aid (IWEDA[1]). IWEDA, however, currently has highly simplistic rules that determine whether the particular device will be adversely impacted by the environment. Typically these rules are based on only the meteorological visibility and possibly one other weather parameter (e.g., fog or precipitation). Moreover, there is no target information associated with IWEDA.

In an attempt to provide more realistic weather impact information on target acquisition devices from IWEDA without increasing the access time for the user, an approach is being undertaken that will utilize the quantitative information available from the Target Acquisition Weapons Software (TAWS[2]). TAWS provides detection ranges for a specific sensor given target details and environmental information. By running TAWS for a large number of environmental conditions and targets, parametric ensemble curves can be pre-computed for use in IWEDA. In concert with the simplicity of IWEDA's rules, these curves will provide the user with *average* detection ranges and additional guidance when in the rule-predicted "marginal" (i.e., amber) or "unfavorable" (i.e., red) IWEDA regions. This allows higher fidelity guidance to be provided in the mission planning or operational support stages.

Work is also being completed to allow the IWEDA user to call TAWS functions indirectly from IWEDA for determination of detailed detection ranges using IWEDA user supplied targets and environmental conditions automatically retrieved from a gridded meteorological database.

INTRODUCTION

In an ideal situation, tactical users would be able to instantaneously determine the detection range for a specific target and operating state by a target acquisition device for a number of different times and locations. Having this information at hand would be of great value in both the execution and planning phases of warfare. As stated in the abstract, however, due to the overwhelming amount of environmental data and target/sensor pairs, this is currently not tenable. As a result, the IWEDA application includes some rudimentary rule based information on the performance of various target acquisition devices. This output can be used in the planning of missions to determine which type of device (e.g., visible vs. infrared) may have an advantage over another in acquiring a target. Figure 1 shows IWEDA output for two acquisition devices and the effectiveness over time. The environmental impact(s) for a specific time and system can be retrieved via a left mouse click on a matrix cell. This information is displayed in the figure as well. A matrix cell with "G" is colored green in a color display and represents no adverse impact, a cell with "A" is an amber (marginal) impact and a red ("R") cell indicates an unfavorable impact. In contrast, Figure 2 shows TAWS output in which detection range values in kilometers are displayed over time. Clearly, a product that could combine the efficiency of the rule based IWEDA with the physics based quantitative output of TAWS would be of great value in tactical situations. This desire led to an ongoing effort in which numerous TAWS runs are completed for each of the existing IWEDA sensors against various target types/operating states, line of sight azimuths, geographic location/season and meteorological scenarios. These results will be averaged and provided as functions of parameters such as meteorological visibility, cloud cover and aerosol type. The end result will be a 4^{th} degree polynomial

parametric curve that will provide a normalized average detection range as a function of visibility. For each IWEDA sensor, there may end up being several parametric curves as a function of meteorological conditions (e.g., aerosol type, cloud amount and type, etc). Thus, the IWEDA sensors' performance can be parameterized to include averaged target information as opposed to the non-target dependent version currently fielded. The remainder of this paper discusses some of the initial results of these ensembles and how they may be incorporated into IWEDA.

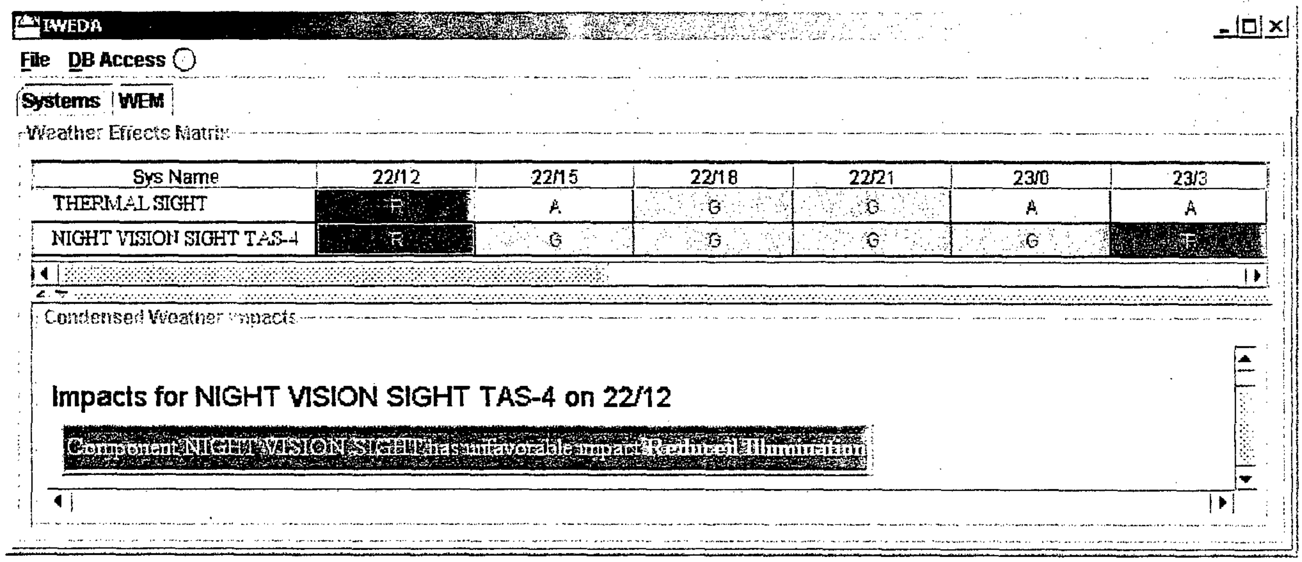

Figure 1 - IWEDA Display for Target Acquisition Devices

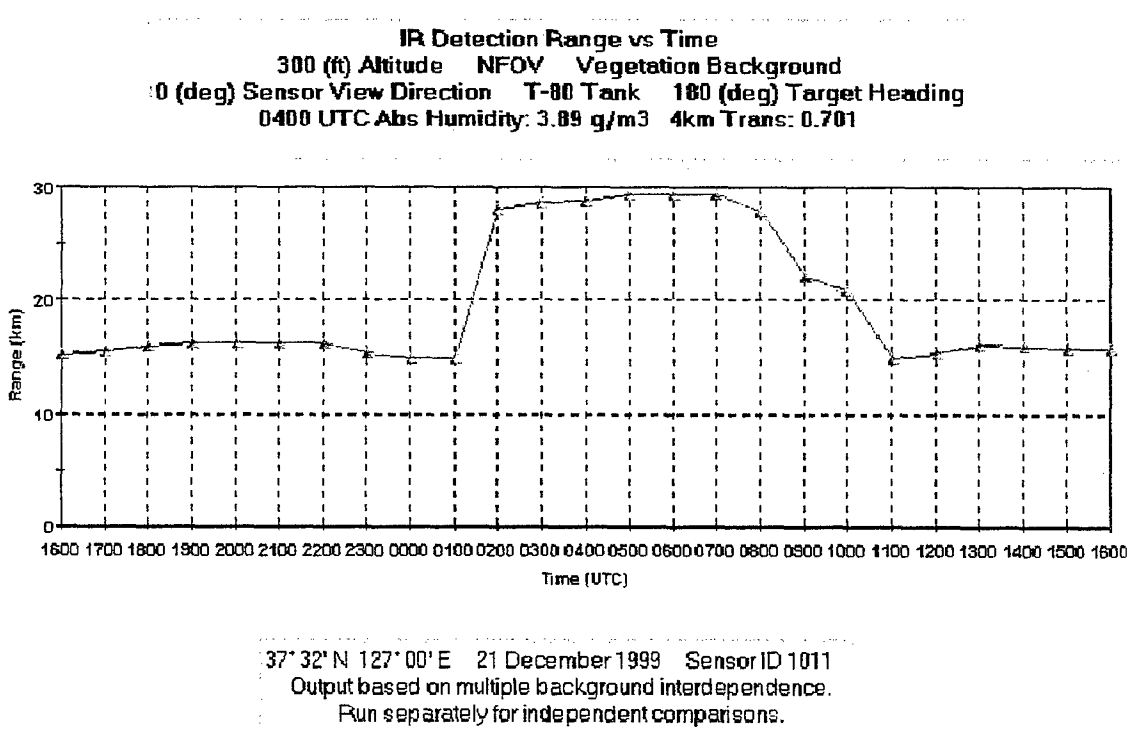

Figure 2 - TAWS Detection Range vs. Time

CURRENT ENSEMBLES

To date, numerous ensembles have been created for 26 narrow field of view (NFOV) IR sensors acquiring a T-80 tank and Armored Personnel Carrier (in both the exercised and off modes) at various times of the day, both with a rural and fog aerosol. The results of these numerous runs have been averaged and fit to several parametric curves as discussed previously. Figure 3 shows the results of some of these ensembles. This figure demonstrates the type of information that will be available for eventual use by IWEDA. Although the curves in the figure are for an ensemble of 26 different IR sensors, the IWEDA ensembles will be computed for the individual sensors corresponding to the current list of available IWEDA sensors. This should produce only a few or several parametric curves for each sensor (as a function of time and/or one or more meteorological parameters, e.g., aerosol type or cloud cover/type). These parametric curves can then be used to determine the normalized average detection range (actual TAWS computed detection range divided by the maximum computed detection range for all conditions). This normalized average detection range will form the underlying basis for the IWEDA favorable, marginal and unfavorable regions as opposed to the current dependence on primarily visibility. Many additional TAWS runs will be required to accommodate the IWEDA sensors and to produce the required ensembles.

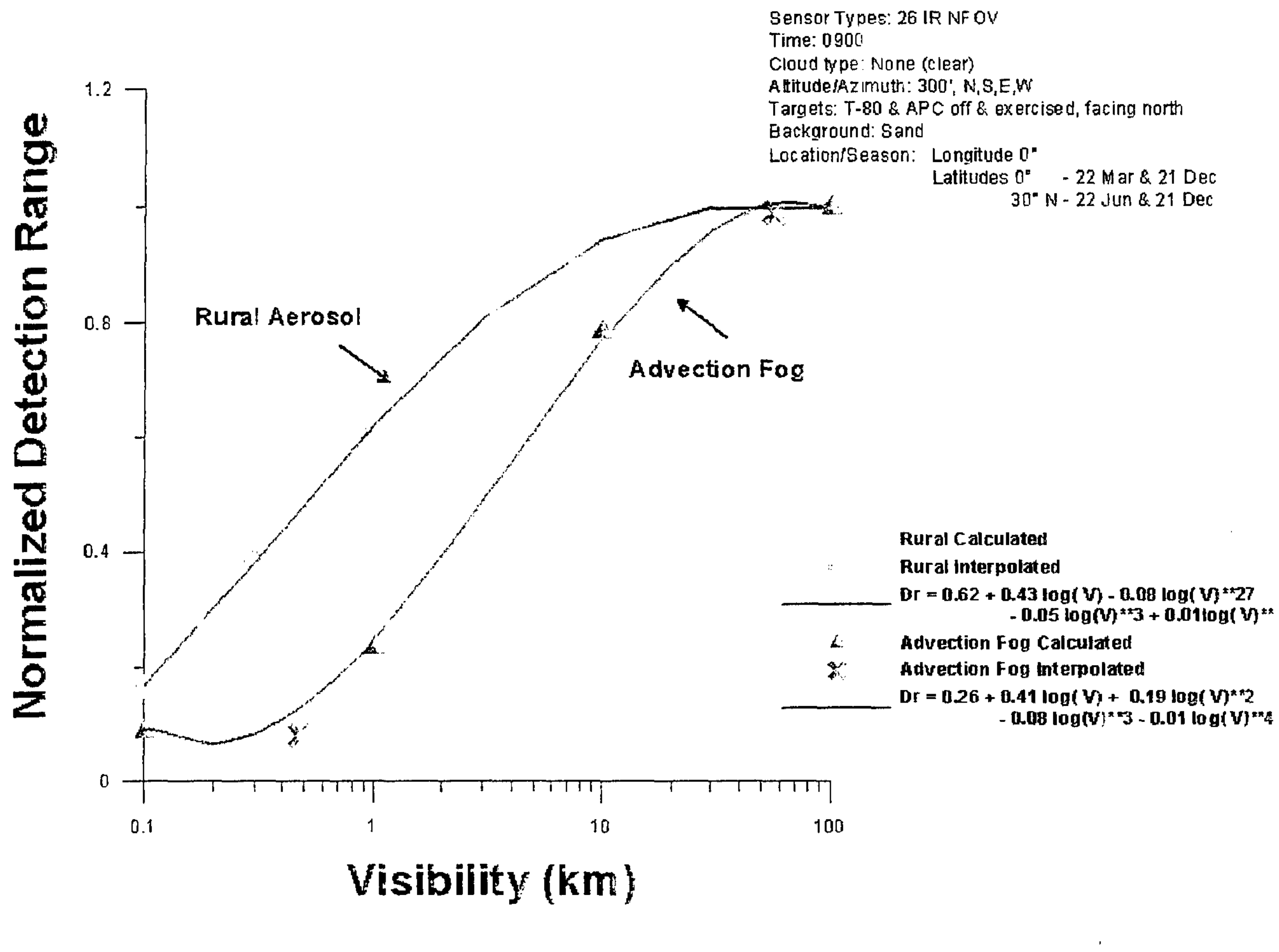

Figure 3 - Rural Aerosol & Advection Fog Parametric Curve Fits

ENSEMBLE INCORPORATION INTO IWEDA

Once the appropriate IR and visible wavelength TAWS runs have been made and the ensembles have been created, the parametric curves for each IWEDA sensor can be plotted and the 4^{th} degree polynomial functions can be determined. There are then two different methods in which IWEDA can incorporate this target dependent normalized average detection range information. These are discussed in more detail in the following sections.

Use of the Polynomial Functions

The normalized average detection range can be computed for each IWEDA sensor and grid point within the IWEDA spatial domain (typically over 2500 points for each forecast period[1]). The polynomial to be used in the computation would be based on the existing meteorological conditions at each grid point. As an example, IWEDA sensor "A" may have a total of 6 polynomial equations to choose from (clear sky, partly cloudy sky and overcast for both rural and fog aerosol). A three-step process is required to determine the IWEDA impact (if any) via use of the polynomial functions. First, retrieve the meteorological parameters for each IWEDA grid point to determine the appropriate polynomial equation to use. Second, compute the normalized average detection range using the polynomial. Lastly, compare this computed normalized average detection value with the threshold value (determined a priori) that has been determined to create a marginal or unfavorable impact. In reality, while the polynomials produce normalized average detection range values, the IWEDA favorable/marginal/unfavorable thresholds will be based on absolute average detection ranges[2]. In this manner. IWEDA will incorporate target information (albeit "average" target signatures) into its output. Until IWEDA sensor ensembles have actually been created, it is unknown how many ensembles will be required for each sensor. The actual number created will be determined somewhat subjectively and will be a function of the magnitude of variability between the parametric curve fits for the various input parameters. For example, if it is determined that cloud amount does NOT significantly affect the average detection ranges for a specific IWEDA sensor, it may be unnecessary to create separate polynomials as a function of cloud cover. Limited results to date for a NFOV IR ensemble average showed little dependence on local time but a significant dependence on whether or not fog was present. This is encouraging, as time of day dependencies would add a level of complexity to the process of determining which polynomial to use. This is due to the fact that the time of day dependence is really a function of the relative azimuth and altitude between the sensor-target viewing direction and the solar position. Thus, for time dependencies, one cannot simply use the time of day for varying geographic locations/seasons but would need to determine the solar azimuth and altitude and then use it accordingly. This is one more computation required for incorporating the polynomial formulation process. Benchmarking will be required to determine the tradeoffs between a large number of ensembles versus increased run time in determining the IWEDA sensor impacts[3]. Obviously the larger the number of ensembles, the better the representation of the meteorological and (any) time of day effects on the average detection ranges. However, having a large number can result in a situation that is overly complex and decreases the IWEDA efficiency and end up defeating the time saving intent of utilizing the ensembles. In the future, the TAWS will be callable from within IWEDA itself, such that the detection range for the IWEDA sensor and user specified target (entered via a graphical user interface that will pop up) may be computed for individual grid points.

Use of the Parametric Curves

A second potential method for utilizing the TAWS ensemble information is to simply use the parametric curves for the individual sensors. In this case, one would also base the IWEDA criteria on the absolute average detection range as previously discussed but would not need to compute the normalized average detection range using the polynomial function. Instead, the graph containing the parametric curve would be consulted a priori to determine the meteorological visibility corresponding to the appropriate normalized average detection range (which again would be determined by mapping an absolute average detection range, e.g., 2.5 km against the maximum average detection range computed for that ensemble) at which values equal to or less would be equated with an unfavorable IWEDA impact (the same would be done to determine

[1] IWEDA provides a map overlay of the spatial variation of the impacts throughout the forecast period (typically a 48 hour prognosis at 3 hour increments). The spatial domain, by default, is a 500x500 km area with horizontal grid spacing of 10 km. This results in a total of 2601 grid points for each forecast period (51x51 grids). The meteorological parameter values at each grid point used by IWEDA are created by a mesoscale model that is run twice a day on the Army's tactical command and control system for weather, the Integrated Meteorological System – IMETS.

[2] Since a *normalized* average detection range of 0.5 for one ensemble may represent an *actual* average detection range of 3 km and in another case 10 km, the *normalized* value does not produce a consistent benchmark between sensors or meteorological scenarios. Thus, a consistent *absolute* average detection range threshold will be determined for the various IWEDA thresholds (e.g., <2.5 km unfavorable, 2.5-5 km marginal and > 5 km favorable) and be applied for all sensors. For IWEDA purposes, the polynomials can either be modified to produce *absolute* average detection ranges or the thresholds can be expressed as a *normalized* value that may vary from sensor to sensor and meteorological scenarios.

[3] Using the previous example of 6 polynomials available for a specific sensor based on cloud amounts and aerosol type, the values for these two meteorological parameters will have to be retrieved from the gridded meteorological database for each of the 2500+ grid points. A decision tree will be coded and utilized to choose the correct polynomial equation to use. This will essentially be a set of "if-then" programming languages statements (e.g., "if cloud amount = 0 and aerosol = fog then use polynomial X"). Obviously the more meteorological parameters that are used as the basis for individual polynomial equations, the lengthier the decision tree (and the longer the sorting and computation process, particularly when one considers the cumulative effect over 2500 grid points).

the corresponding visibility or visibility range for the marginal impact). Using Figure 3 as an example, assume for the moment that these two curves represent the response of IWEDA sensor "A" to visibility for a fog aerosol and a rural aerosol. Also assume that the maximum average detection range computed for all of the ensembles was 12.5 km. Then the unfavorable impact for this sensor (from footnote 1, an absolute average detection range of 2.5 km) would be represented by an average normalized detection value of 0.2 (2.5 km/12.5 km) or less. Reading the corresponding visibility value for this normalized average detection range for the advection fog case yields a value of approximately 1.0 km and just over 0.1 km for the rural aerosol case. This provides a simpler and faster determination of the IWEDA impact level than using the polynomial equations. as it is neither necessary to determine which polynomial to use nor compute the detection range using the polynomial. In this case, the actual average detection range of sensor "A" is not available for display to the IWEDA user as it would be if the polynomial equation was used. However, as mentioned previously, it is anticipated that the IWEDA user will soon have the capability of computing the actual detection range for specific grid points on demand, thus this shortcoming is deemed non-critical in light of the increased efficiency (benchmarking will be required to determine whether the computing time difference is significant).

To date, only NFOV IR sensor ensembles have been produced. IR sensors, in general, should be less sensitive to the relative angle between the sensor-target viewing direction and the solar position. For visible sensors, however, it is anticipated that the angular dependence (i.e., time of day) will be more significant, particularly for cases when the sun is unobscured. This is due to the fact that the sun will cause target shadows in the visible wavelength. Reflected light off target facets may also contribute to the angular dependence. Careful thought will need to be given as how to best represent visible sensor ensembles without overly complicating the situation and creating a large number of ensembles.

SUMMARY

Work has been initiated to incorporate target effects into the rule based IWEDA application via an ensemble approach. This effort has the potential to provide more realistic guidance to the IWEDA user regarding the environmental impacts on the current inventory of IWEDA sensor devices. A potential drawback is the possibility of making the underlying IWEDA application more complex if too many parametric ensembles are added. On the other hand, if too many parameters are included in the individual ensembles (resulting in relatively few ensembles), a danger exists of simply smoothing out the target effects resulting in output that has added little if any value to the situation. The ultimate solution is to utilize TAWS to compute the actual detection ranges for each of the multitude of IWEDA grid points (using the unique meteorological values) for a user specified target for each sensor. Due to tactical computing limitations, however, this capability is some years off. In the interim, allowing the user to input a specific target for an individual IWEDA grid point via a simple GUI to determine the detection range will provide additional information. Coupled with the initial guidance on the effectiveness of the sensors from the parametric curves, this will hopefully provide a satisfactory solution.

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